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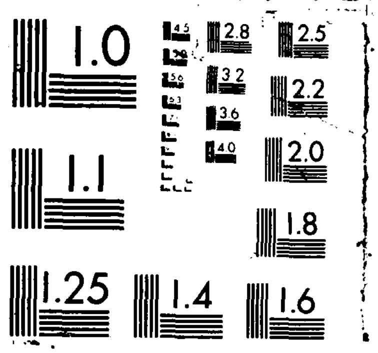
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The final report of the JSEP (Joint Services Electronics Program) in Electromagnetics, Quantum Electronics, Solid State Electronics, Materials and Devices, and Information Systems is presented.

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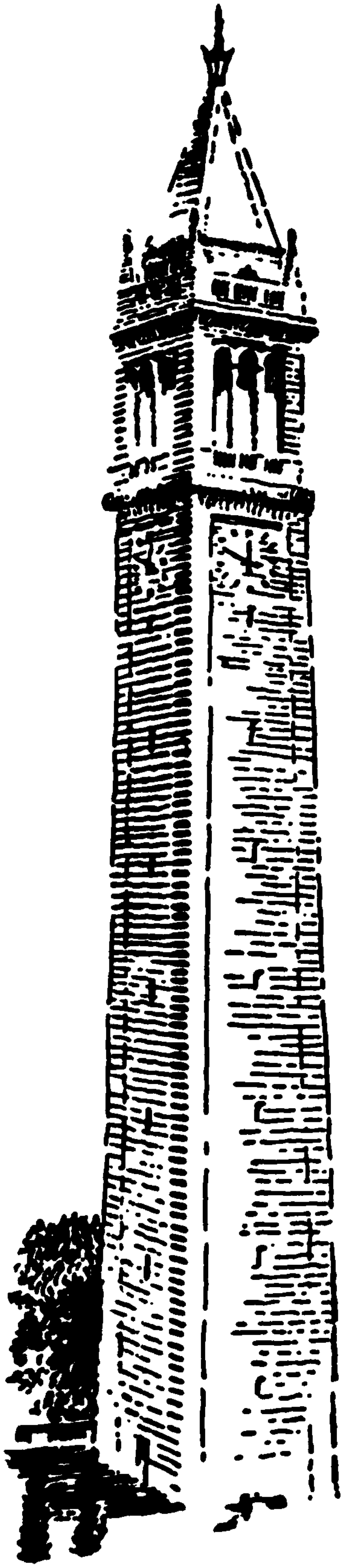

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JOINT SERVICES ELECTRONICS PROGRAM

Final Report
(Contract F49620-84-C-0057)
1 May 1984 - 30 April 1987

W.G. Oldham

June 1987

Prepared for:

Air Force Office of Scientific Research (NE)
Bolling Air Force Base
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A. OVERVIEW

The Joint Services Electronics Program continues to be a significant factor in the ability of the laboratory to respond to new research opportunities. Examples during the present three-year grant include the start up of activities in parallel computation, neural networks, electro-optic probing, and GaAs on Si. The continuing work in superconductive electronics has given us a head start in the recent resurgence of this field. The JSEP-initiated MBE materials program has led to a number of interesting research results and has stimulated a growth in this activity within the Electronics Research Laboratory. A new faculty member whose speciality is MBE has been recruited, and is a participant in the new JSEP Research Program.

Some highlights of the three-year JSEP contract include:

1. Laser Devices based on Integrated Optics Concepts and Theory

A ten-element semiconductor laser array using ridge-guide index guiding was successfully constructed. The device included the novel feature of a provision for partial pumping of the coupling region between the stripes. A single-lobe far-field pattern was achieved [1]. A theoretical study led to more advanced designs. The latter is a five-element array with graded pumping, and it maintains single-lobe mode pattern up to the highest output power available.

A self-consistent computer model was developed for the waveguide array with coupling provided through the evanescent fields between guides. This model accounted for the effect of field upon carriers and carriers upon field, including diffusion effects, stimulated emission, and spatial hole burning. It gave patterns of the array modes (supermodes) in good agreement with those measured on our fabricated models, and demonstrated the difficulty in operating in only one array mode since several of these modes had calculated thresholds close together. The model was extended to account for more than one lasing array mode [1]. The pattern of a given mode is found to change markedly as another mode starts to lase. A single lobe pattern is observed up to 4.6 times threshold without beam broadening [2] in the fabricated device. Quite a different approach--that of using an external cavity with spatial filters to select the desired mode--has also been demonstrated. Using a gradient-index (GRIN) lens as the Fourier transforming device, a very compact and rugged combination results [3-4].

2. GaAs Devices

Films of GaAs on Si were grown with the purpose of understanding (and reducing) stress and threading dislocation count. TEM of studies and RAMAN scattering revealed the stress distributions [5-6]. Using the electro-optic probing technique we have succeeded in measuring the standing wave ratio in a GaAs coplanar waveguide at frequencies of 8.2107 GHz and 12.310 GHz [7]. The method has also been demonstrated to provide a valuable tool for ascertaining the surface condition of a semiconductor after processing [8].

3. Electromagnetics

Major progress in the ability to perform computations on difficult geometries was achieved under JSEP support. The Boundary Element Technique and the Unimoment Method were demonstrated in efficient codes [9-10].

Starting from the very simple concept of space-time computation of a one dimensional wave equation, the basic techniques and the associated theories of time domain numerical methods can be stated. These involve the relations between discretization, computational procedures and stability. It has been possible to obtain methods of initialization and termination of the computations and numerical treatments of dielectric interfaces. One such method of "conforming boundary elements" and the "Poynting vector method" of simulating radiation conditions have been developed. These techniques are quite essential in saving storage space and computing costs, which are especially important when the method is applied to large scale computations. Use has been made of Gaussian primary fields rather than the often used step sinusoids because time sequence of the Gaussian results are more graphically presentable, and the CW results can readily be obtained from their FFT's.

The one dimensional wave equation with dielectric interface has been successfully programmed with the results displayed on CRT as they are computed. Indeed, time domain electromagnetics is a very effective method in providing physical insight to fields and waves, as well as a powerful computational technique for engineering applications.

Direct time domain computation of Maxwell's differential equations will soon become a practical technique because of the availability of super-computers. In the time domain computations the Point-

Matched finite element method is chosen as the main feature which includes the discretization of equations, conforming mesh generation, dielectric and metallic interfaces, numerical stability and simulation of radiation conditions. Numerical results of scattering of Gaussian pulses have been obtained in time sequences.

4. Solid-State Electronics

The variables which control hot-carrier induced device degradation have been identified. The quality of the interface and the channel electric field play critical roles. A method has been developed to compare the interface quality of different devices (different fabrication technologies) so that the degradation rates of new devices may be predicted [11]. The source of device degradation is hot-electron emission. A comprehensive model for channel hot-electron emission in MOSFETs has been developed. Geometrical effects from narrow and short channels are included so that scaling predictions may be made. A physical model for the degradation, related to the hot electrons, has been proposed. The very hottest electrons (> 4eV) break Si-H bonds, freeing a proton to diffuse away [12].

The physical mechanisms responsible for oxide breakdown and wearout have been studied in order to explore several possibilities for process improvement and modeling. The oxide charge has been correlated to breakdown, hole generation and trapping rate. It has demonstrated that radiation-hard process produces oxides with longer lifetimes. Further, a mathematical model has been developed that characterizes oxide "defect" density and predicts oxide failure rate and screen yield.

5. Information Systems and CAD

A definite solution has been obtained to the following fundamental problem: When does a network containing nonlinear monotone resistors, dc sources and linear controlled sources possess a unique solution? The uniqueness criteria is couched in strictly topological terms. In particular, the uniqueness of a large class of practical nonlinear circuits can be determined, often by inspection, by checking for the presence of a new and fundamental topological structure called a cactus graph. The paper [13] was honored as the *1985 IEEE Guillemin-Cauer Prize Paper* (the most prestigious award from The IEEE Society on Circuits and Systems).

A Protocol Workroom Facility has been completed which will provide a unique environment for experimental research in Communications Network and Distributed Systems. The channel emulator can emulate a large variety of network topologies including bus, rings, point-to-point, and radio.

The basic work on algorithms for automatic placement and routing has proven to be an important addition to CAD methodology. The "building block layout" system, or BBL, has been supported by JSEP for several years. A prototype of the automatic placement algorithm for two-level hierarchy with rectangular modules has been implemented. Recently several tests were performed which show a 10-25% reduction of chip area for BBL layouts compared to other systems [14].

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6	15

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